Development of a Coherent Differential Absorption Lidar for Range Resolved Atmospheric CO_2 Measurements

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Acknowledgement: Research and development under NASA Laser Risk Reduction Program funded by NASA Earth Science Technology Office (Program Director: George Komar)

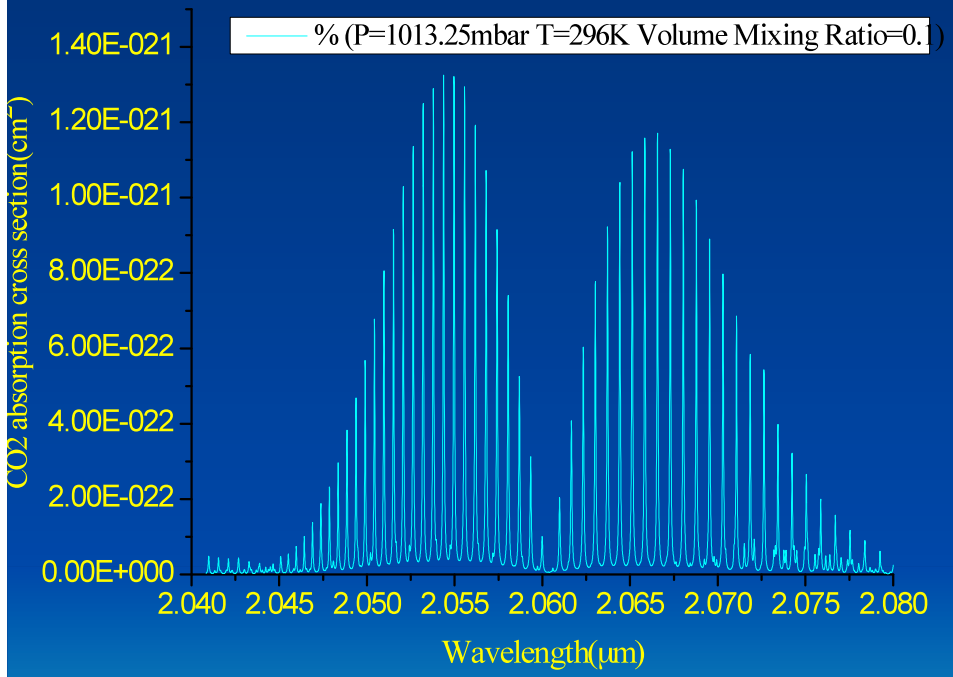
Outline

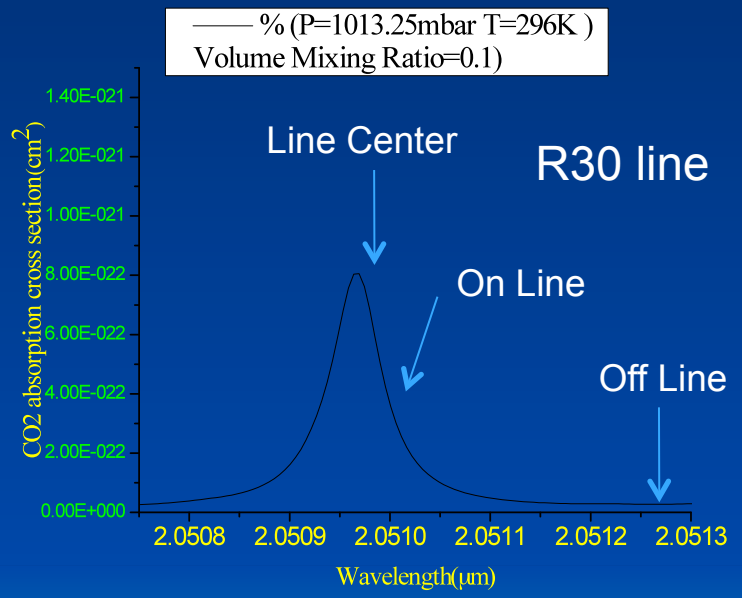
- 2-micron Pulsed Lidar Approach for CO_2 Measurement
- 2-micron Pulsed Lidar DIAL/IPDA Roadmap
- High Energy 2-micron Pulsed Lidar- for Mobile Ground and Airborne CO_2 Profiling
  - Double Pulse Laser Transmitter for DIAL
  - High Accuracy Wavelength Control and Switching
  - Ground Based High Energy Coherent CO_2 DIAL Demonstration
- Summary

Pulsed Lidar Approach

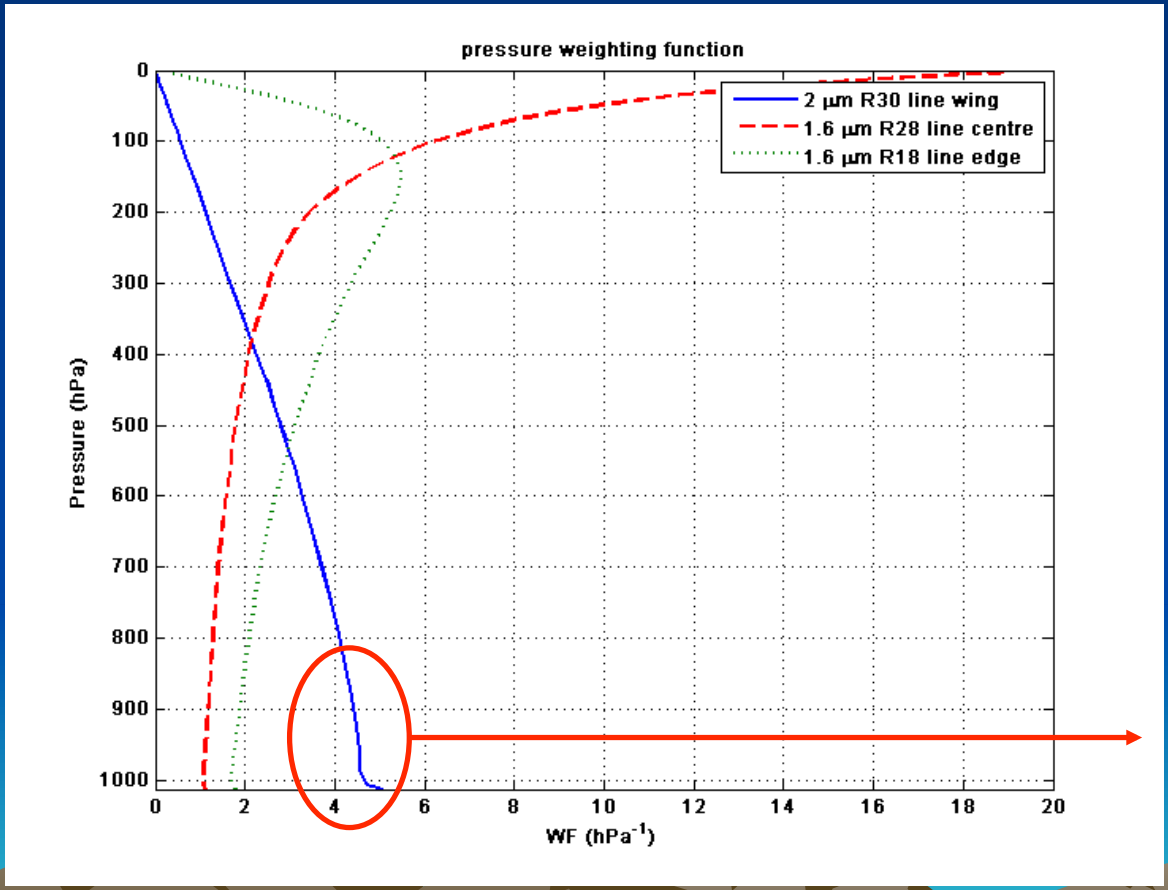
- A CO_2 profiler from ground or airborne platform is an indispensible validation tool for ASCENDS mission
- For column measurements, the pulsed lidar approach can eliminate contamination from aerosols and clouds to yield high accuracy measurements
- The pulse approach can determine CO_2 concentrations as a function of distance with high spatial and temporal resolution, a valuable data product that is not currently available
- The weighting function in the 2-μm region is most favorable for making CO_2 measurements near the surface and PBL, where the sources and sinks of CO_2 are located

CO_2 Absorption Line at 2-micron





Requirement on high sensitivity of the WF to the lowest atmosphere



Selection of the **R30 CO_2** absorption line at **2050.967nm** in the $(20^01)_{III} \leftarrow (00^00)_I$ band of CO_2 as one of the most suitable line for DIAL measurement from space.

Weighting function peaking in lowest part of atmosphere

Courtesy: Fabien Marnas, LMD/IPSL

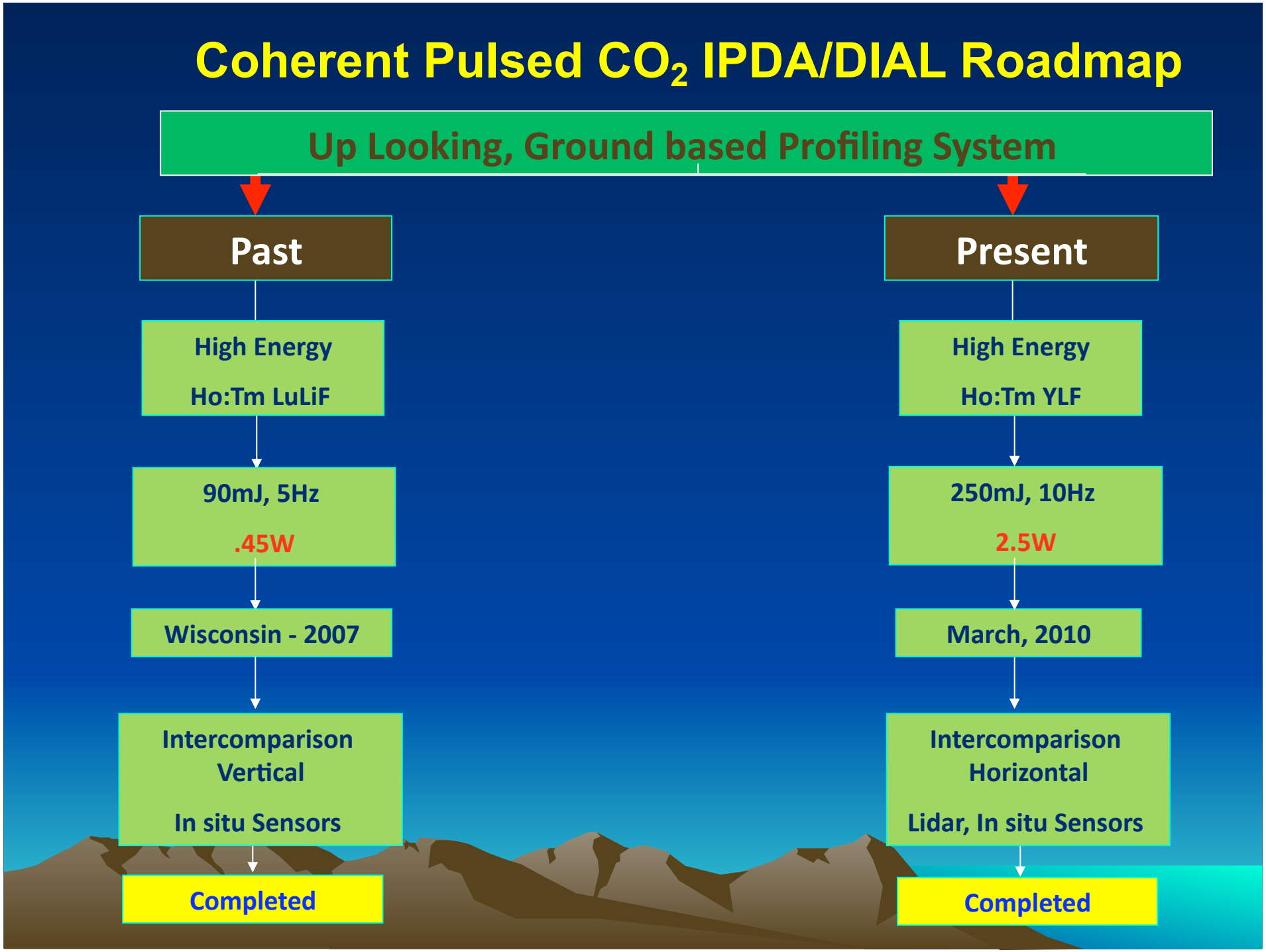
Approach Rationale

- High energy ground based mobile system/Airborne DIAL system for ASCENDS instruments validation
  - Unique range-resolved profiling – critically needed
  - Unique up looking profiling system up to 4 Km
  - Matured, compact, highest energy coherent DIAL System
- High Repetition Rate 2-micron DIAL System
  - High Efficiency
  - High accuracy and precision
  - Higher temporal and spatial coverage
  - Airborne system capable of providing profiling in planetary boundary layer and free troposphere, as well column content – unique capability

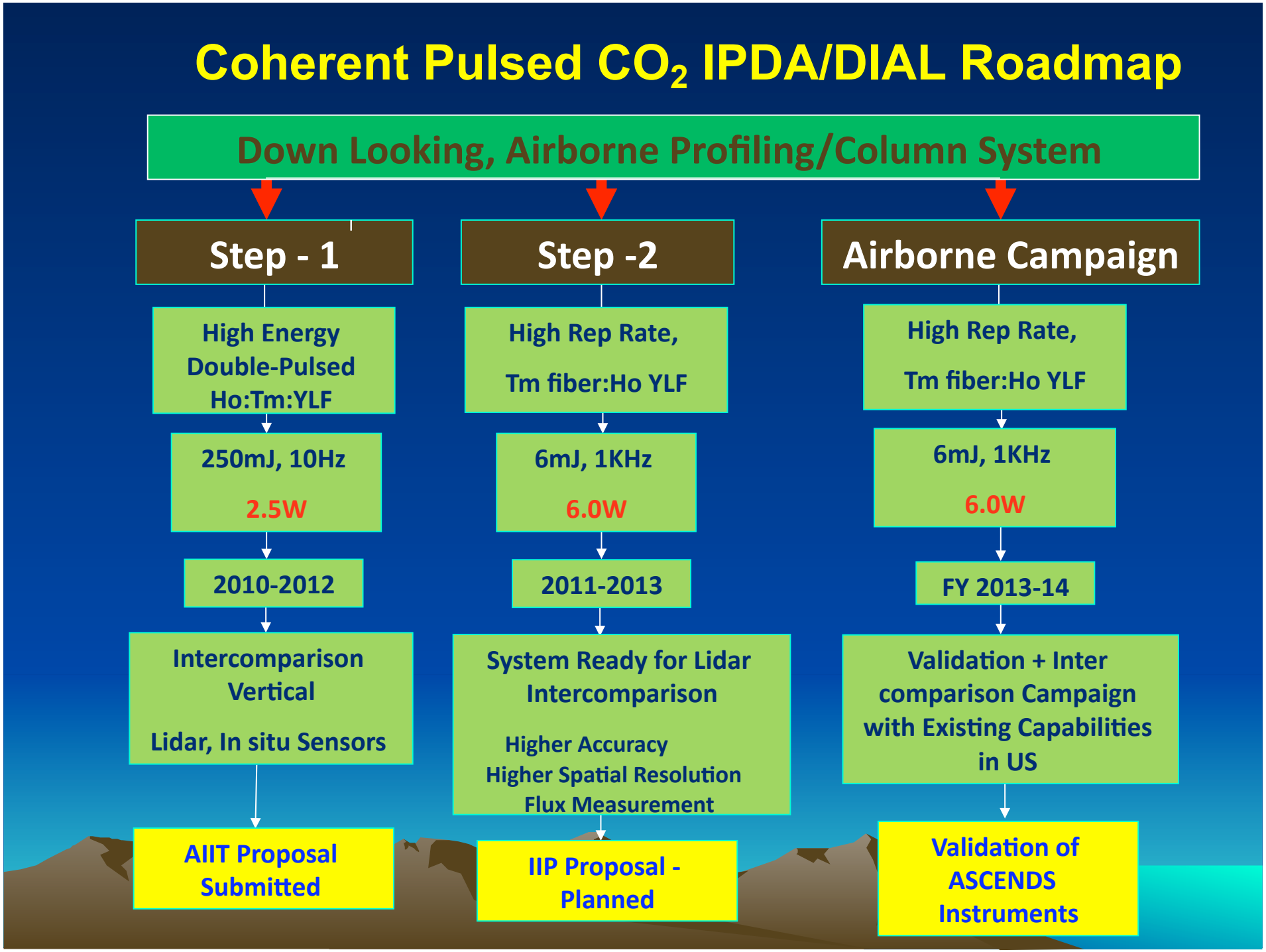
Plan

- Through LRRP funding, NASA LaRC has developed two unique technological approach and associated hardware to provide CO_2 profiling from ground, as well as airborne
- High Energy – Low Repetition Rate
  - Demonstrated high precision ground based CO_2 profile measurement
  - Plan to fly a LRRP developed compact packaged 2-micron lidar (Step -1)
- Moderate Energy – High Repetition Rate
  - Develop a compact airborne high repetition rate DIAL System (Step – 2)

Coherent Pulsed CO_2 IPDA/DIAL Roadmap



Coherent Pulsed CO_2 IPDA/DIAL Roadmap



Pulsed CO_2 IPDA/DIAL Column Roadmap

Column, Down Looking, Space borne System

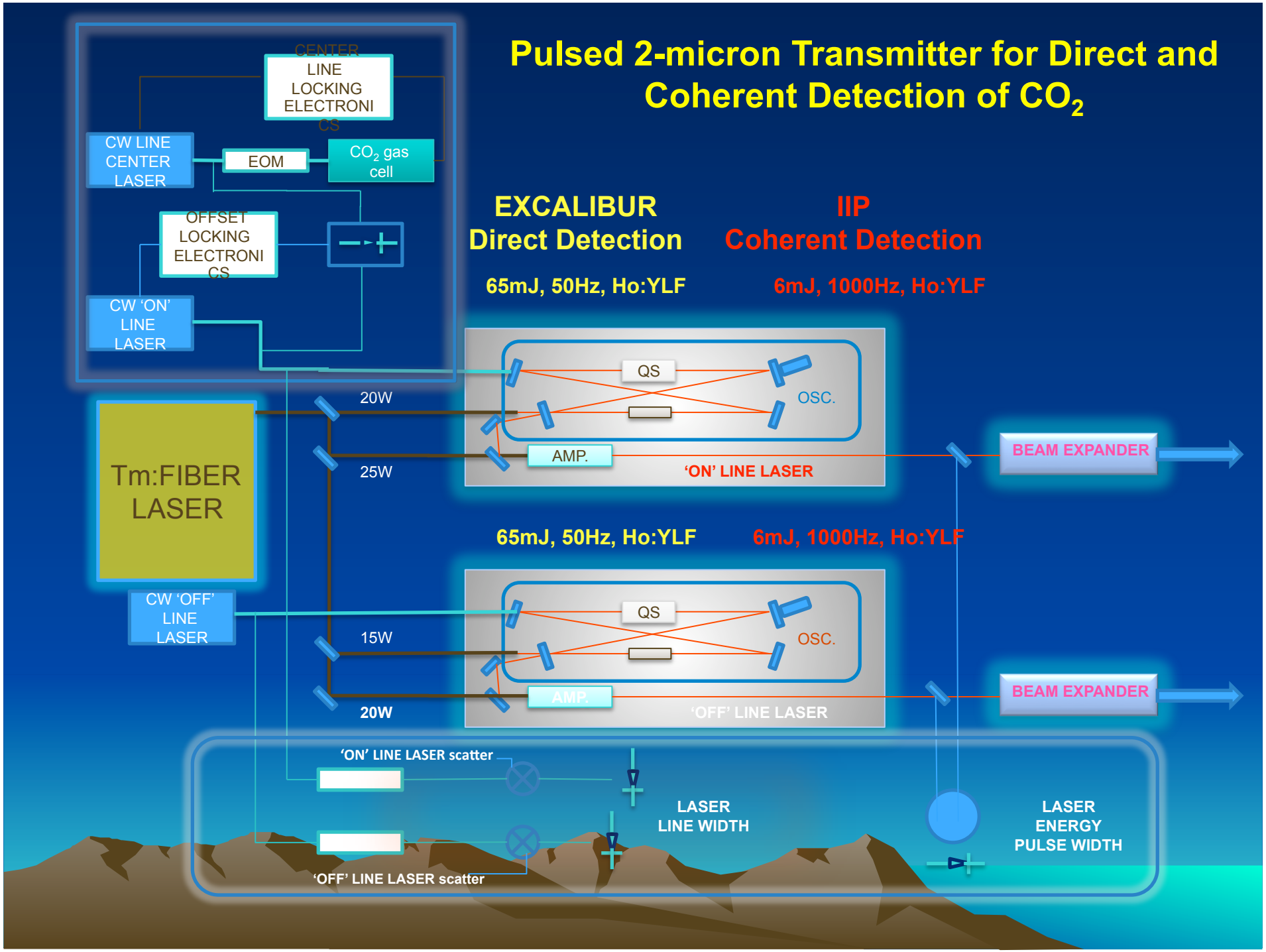
Coherent

- Space borne Column
- High Rep Rate, Tm fiber:Ho YLF
- 1mJ, 7.5KHz Injection Seeded
- Valid Approach if Ultra-low noise Detector for Direct Detection is not Available

CO_2 profiling from space is currently not feasible due to lack of mature technology. The energy and receiver technology needs to advance by more than an order of magnitude. Laser does not exist and development of an appropriate laser will require at least 5-7 years of sustained efforts with lot of funding.

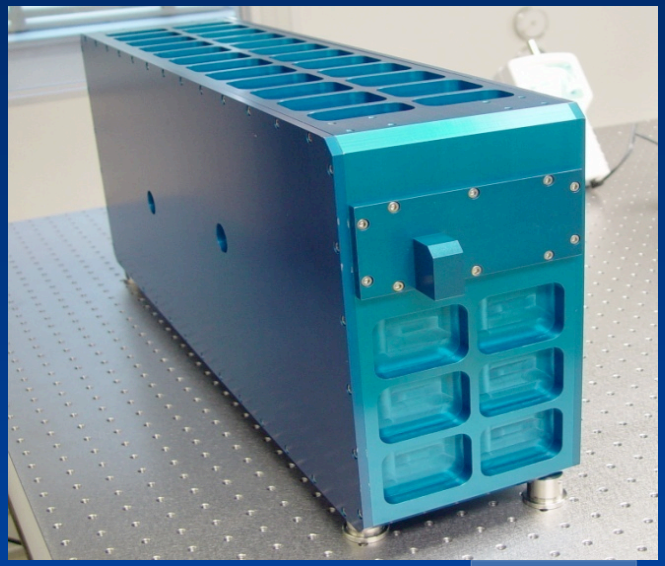
Direct

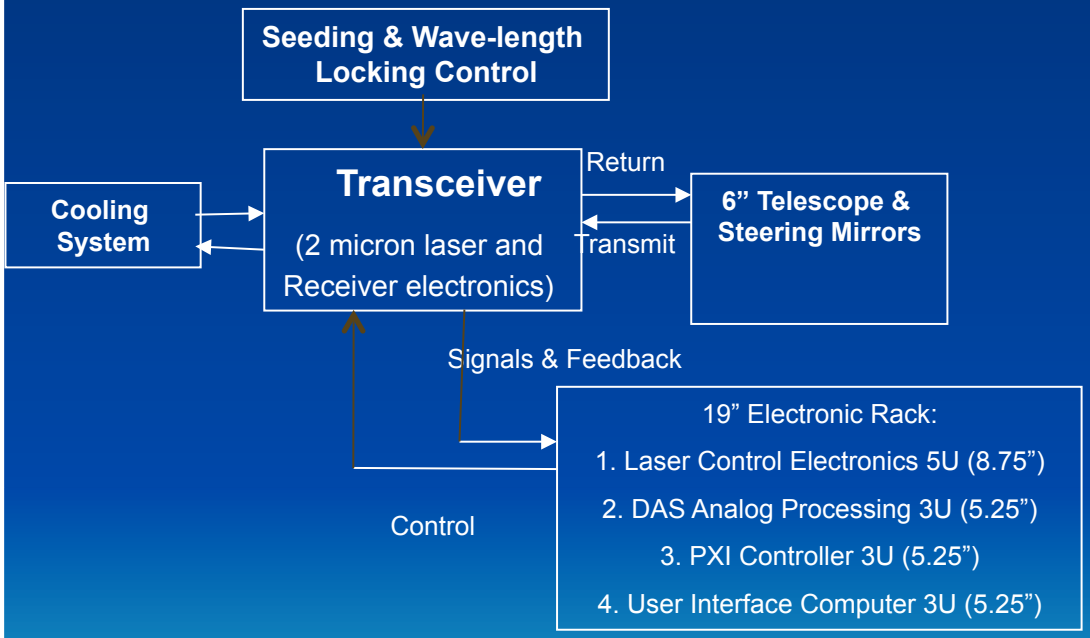
- Space borne Column
- Mod Energy, Mod Rep
- 65/50 mJ, 50 Hz Injection Seeded Large Telescope, Ultra-low noise Detector
- Preferred Approach if low NEP Detector is Available - EXCALIBUR prefers this approach ESA is developing detector

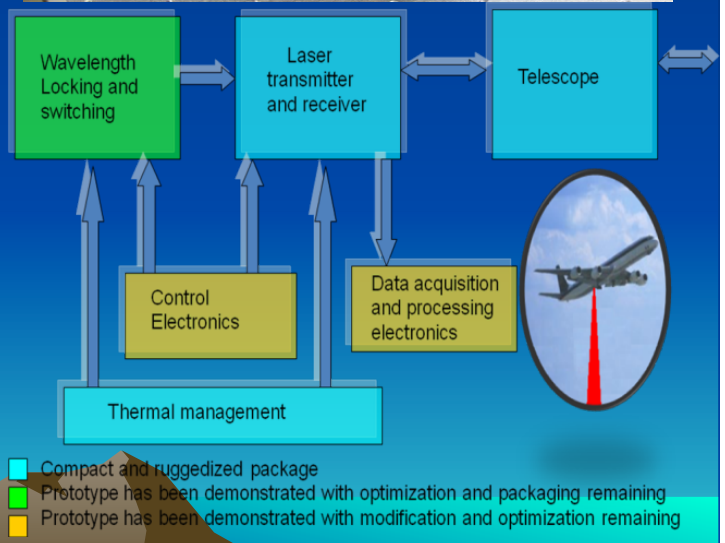

Pulsed 2-micron Transmitter for Direct and Coherent Detection of CO_2
CENTER LINE LOCKING ELECTRONICS
CW LINE CENTER LASER
EOM
CO_2 gas cell
OFFSET LOCKING ELECTRONICS
CW 'ON' LINE LASER
EXCALIBUR Direct Detection
IIP Coherent Detection
65mJ, 50Hz, Ho:YLF
6mJ, 1000Hz, Ho:YLF
Tm:FIBER LASER
20W
25W
QS
OSC.
AMP.
'ON' LINE LASER
BEAM EXPANDER
CW 'OFF' LINE LASER
15W
20W
'OFF' LINE LASER
'ON' LINE LASER scatter
'OFF' LINE LASER scatter
LASER LINE WIDTH
LASER ENERGY PULSE WIDTH

Pulsed Coherent CO_2 DIAL

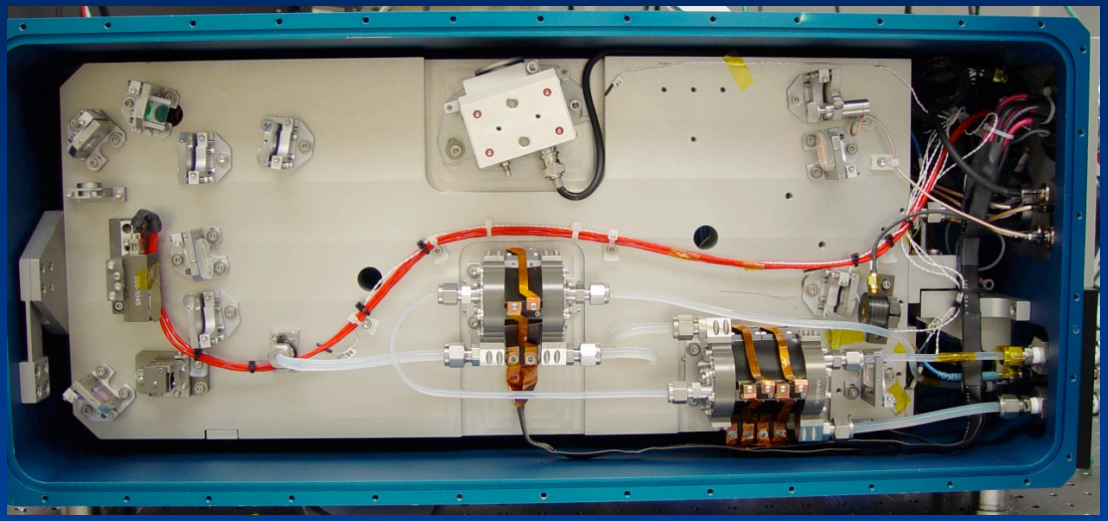
- Pulsed 2-micron laser transmitter
- 250 mJ/10Hz
- Coherent DIAL
- Provide CO_2 profiling/column density measurement



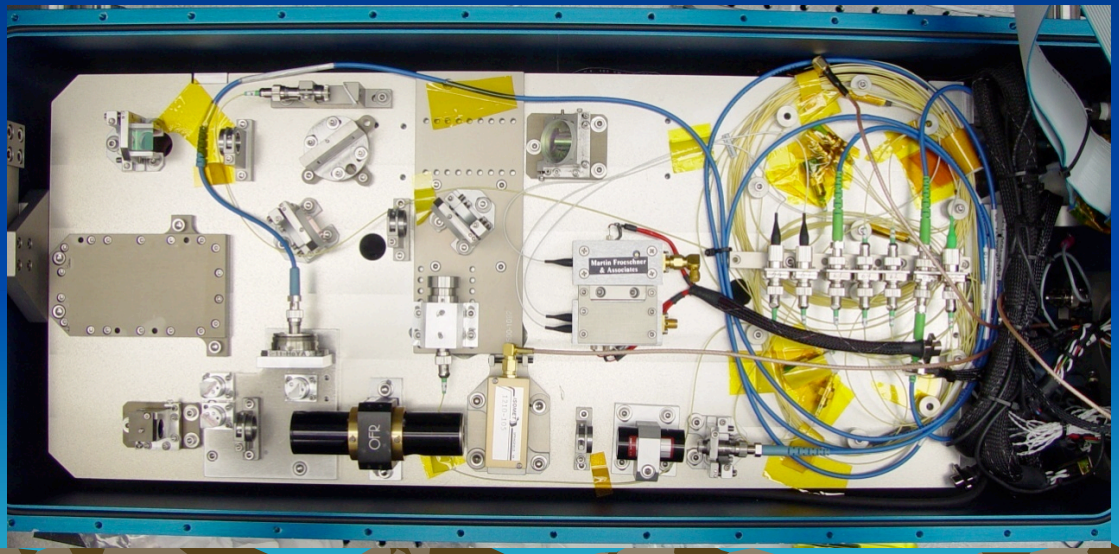




Coherent CO_2 DIAL Transceiver

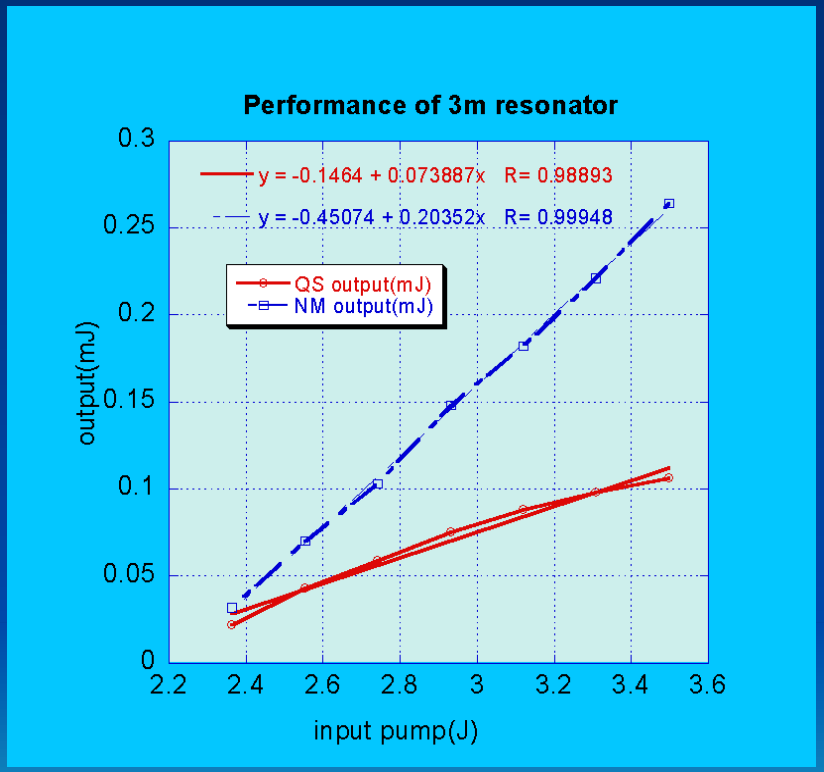


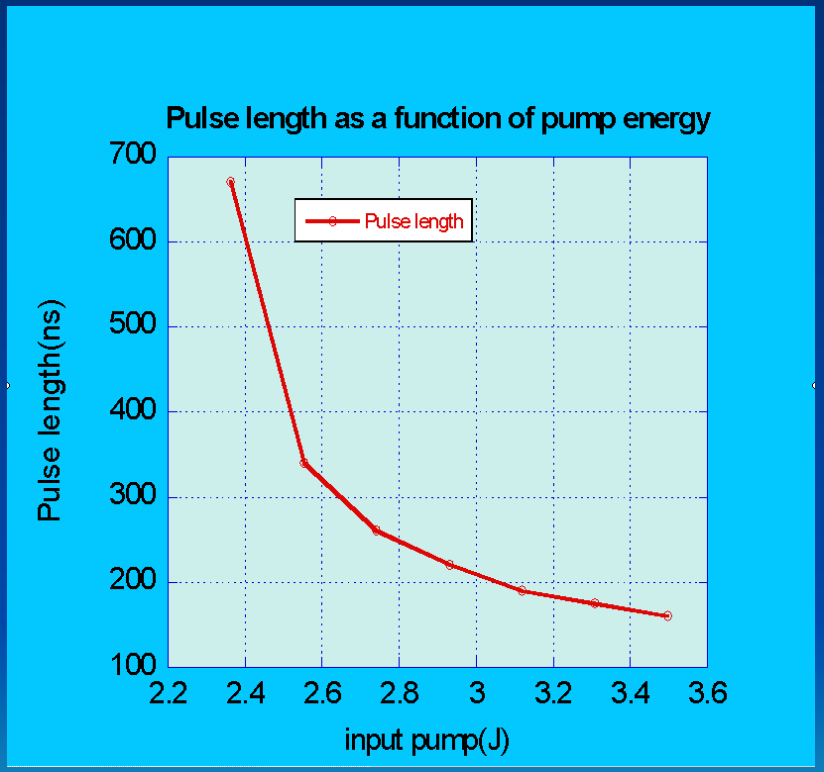
Transmitter Side



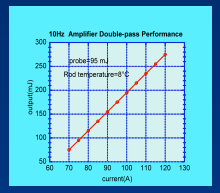
Receiver Side

10 Hz Oscillator Performance



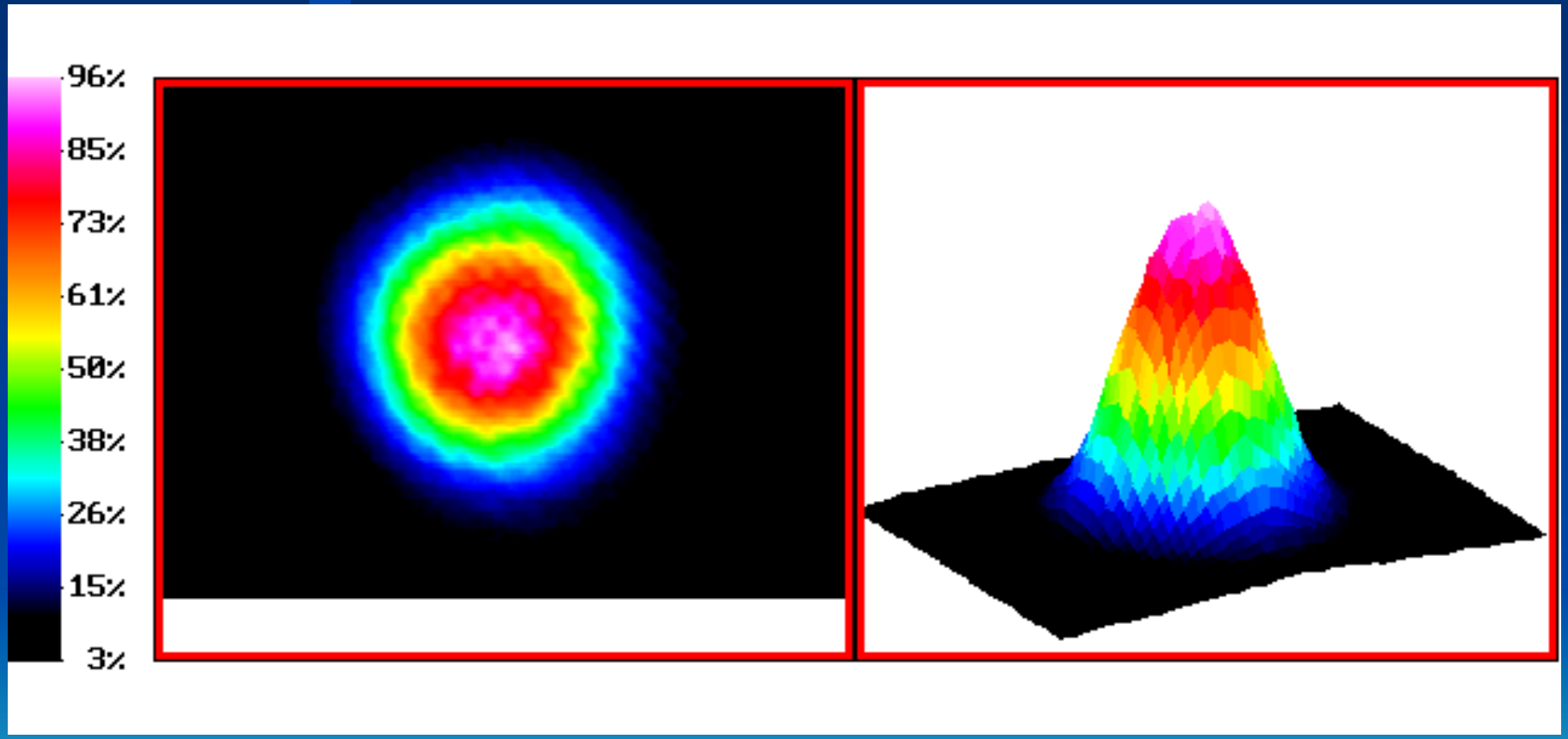


Double Pass Amplifier Performance

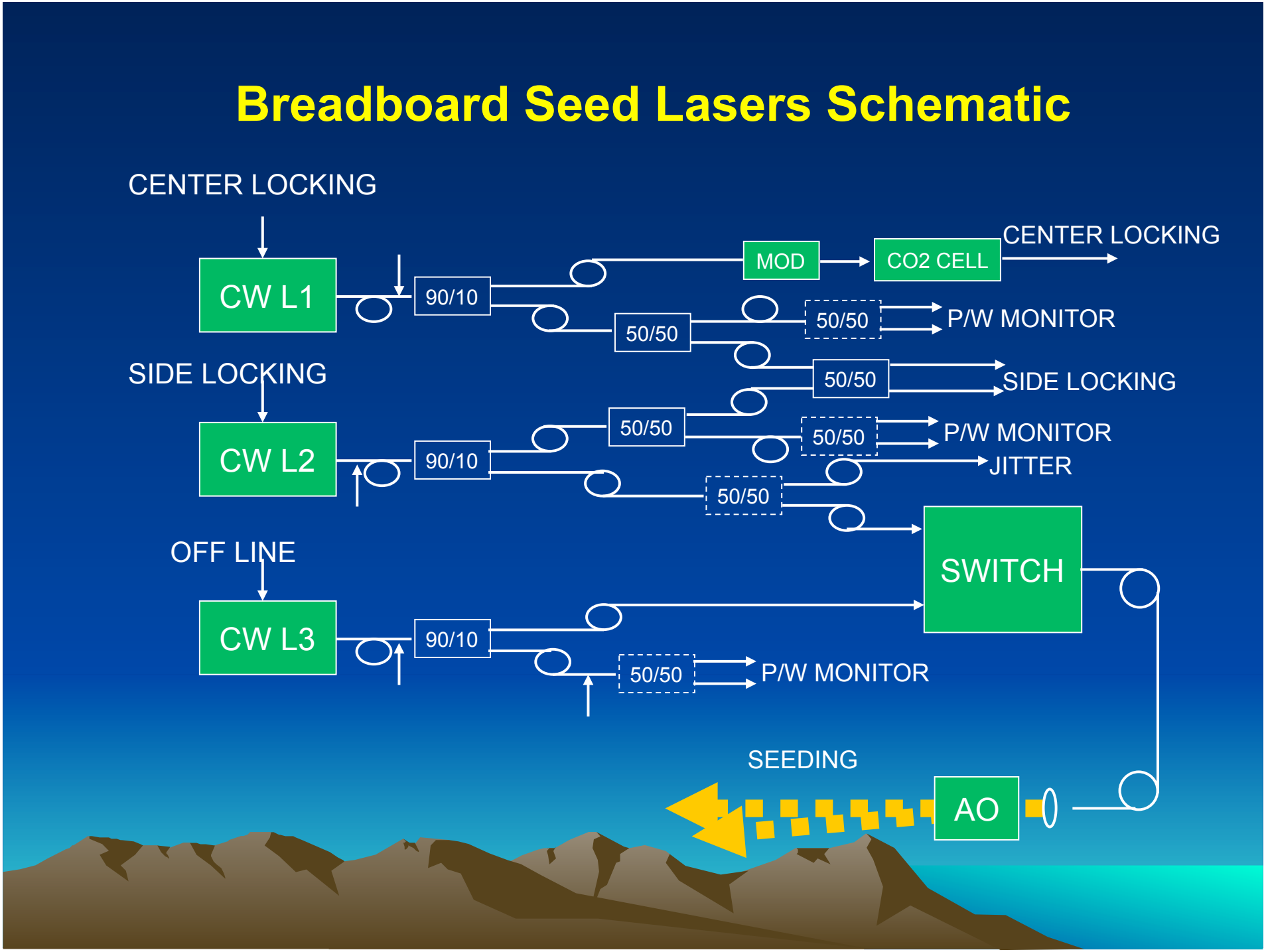


Amplifier gain: double pass ~3

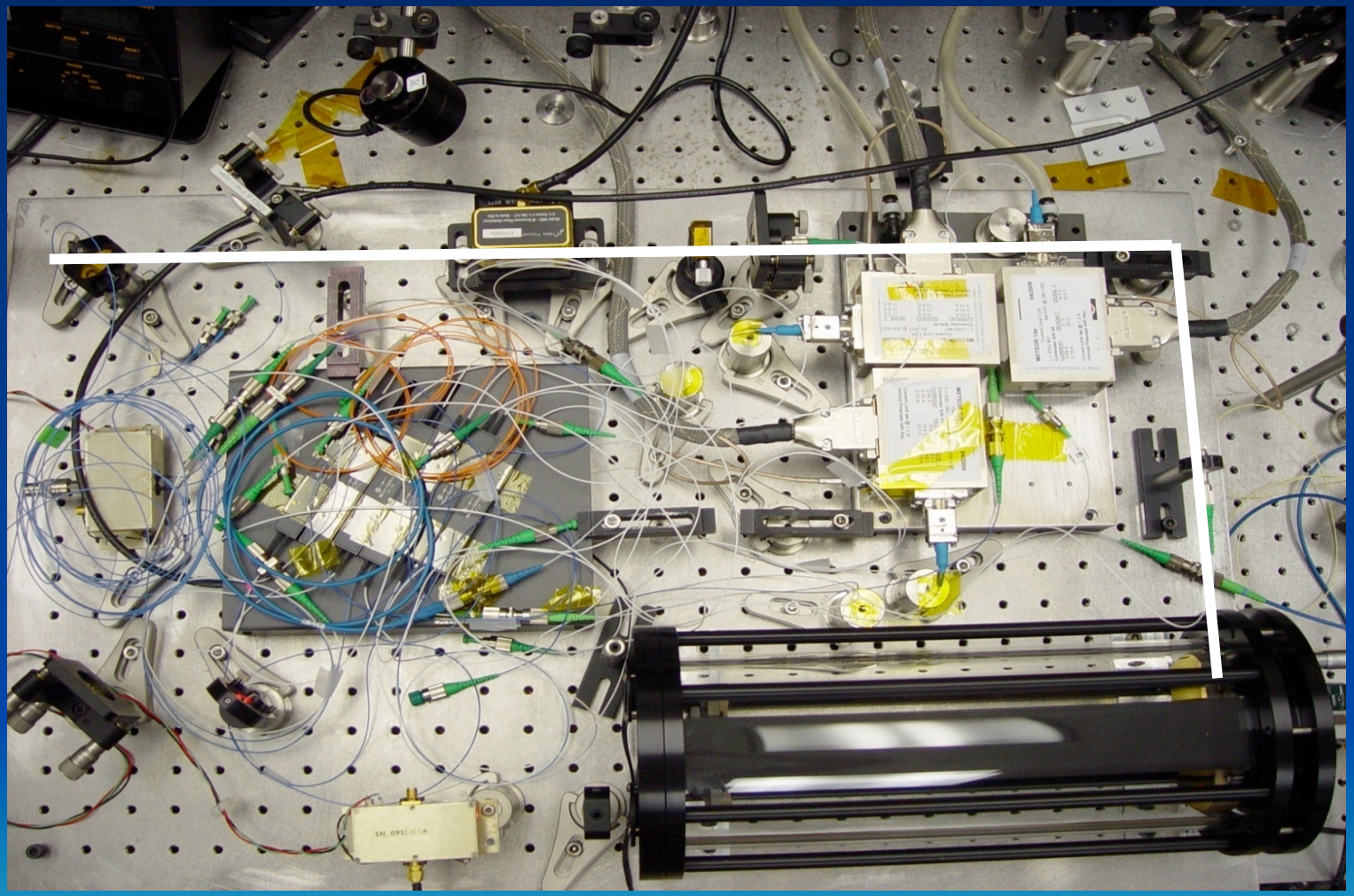
Laser Beam Profile



Breadboard Seed Lasers Schematic

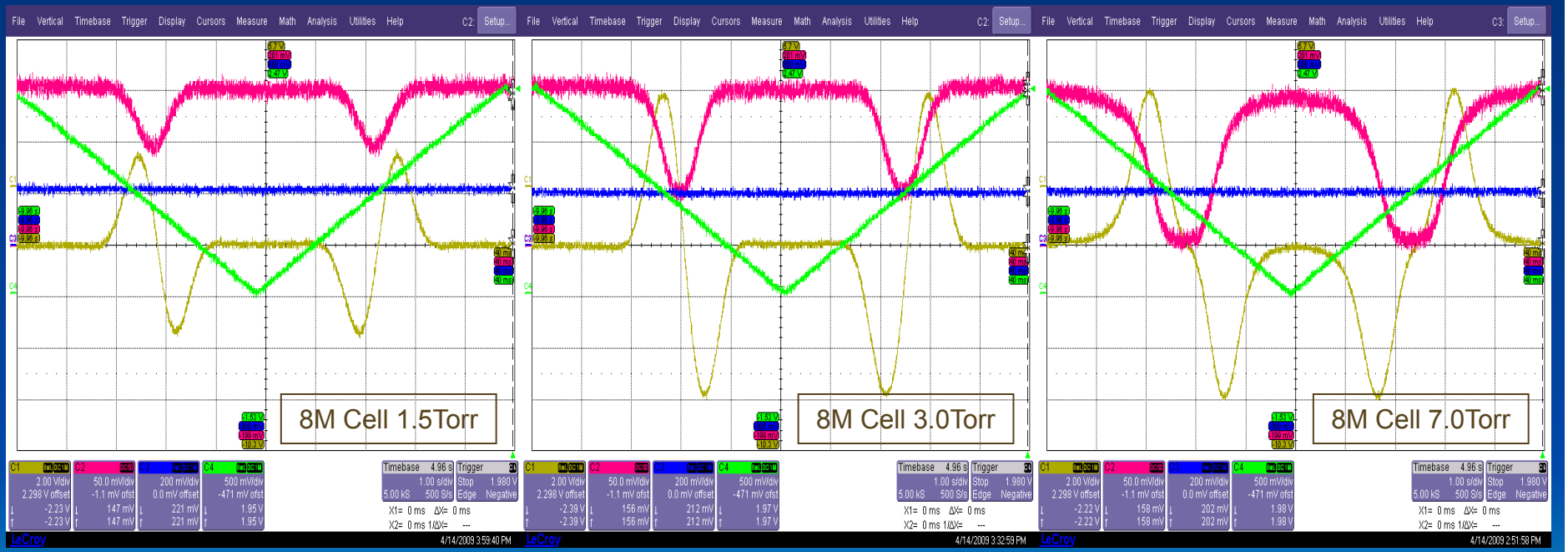


BREADBOARD SEED LASER LAYOUT_2



FRERQUENCY LOCKING AT CO_2 ABSORPTION LINE CENTER

---- ABSORPTION & LOCKING CURVES



8M Cell 1.5Torr

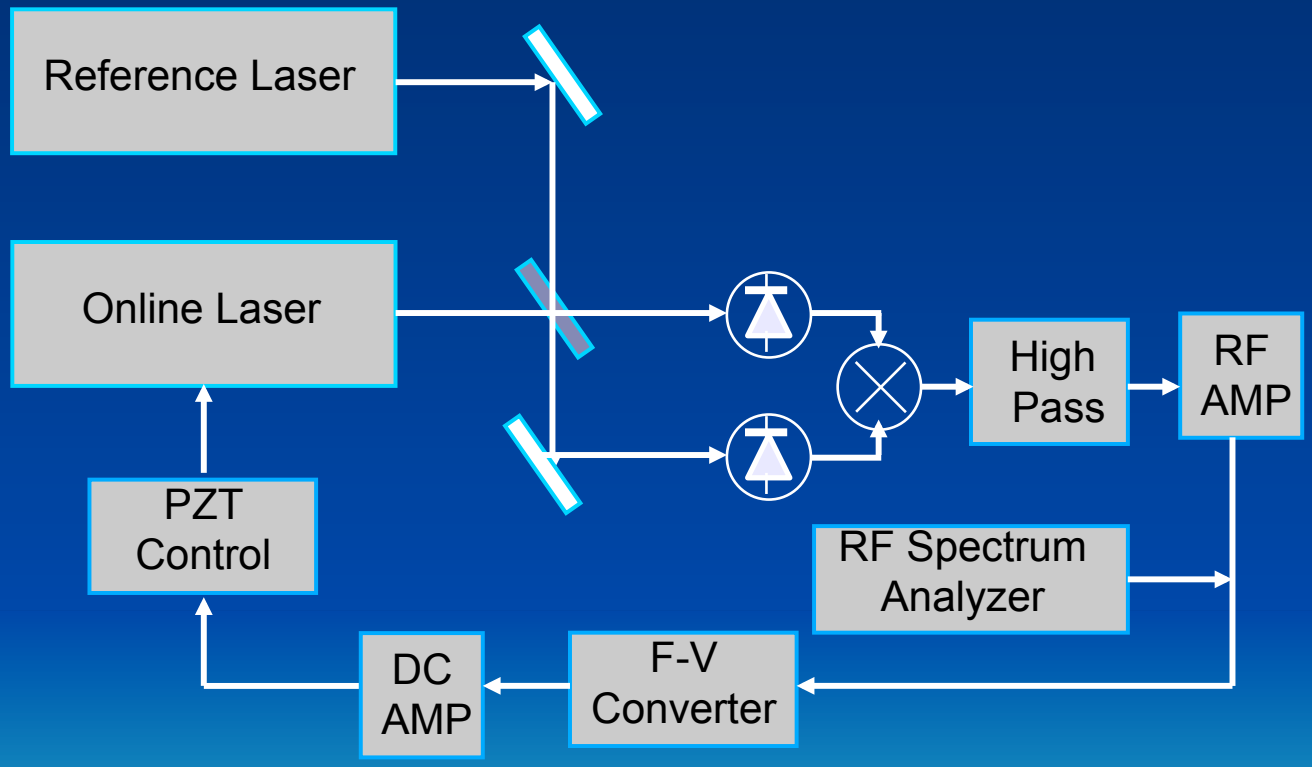
Scanning

Normalization

Absorption

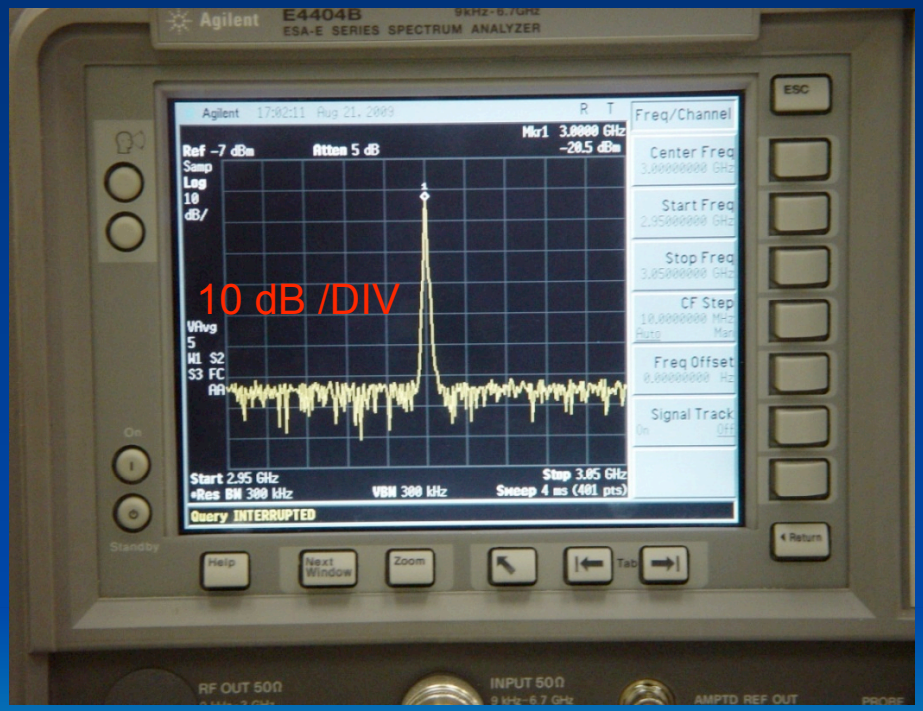
Locking

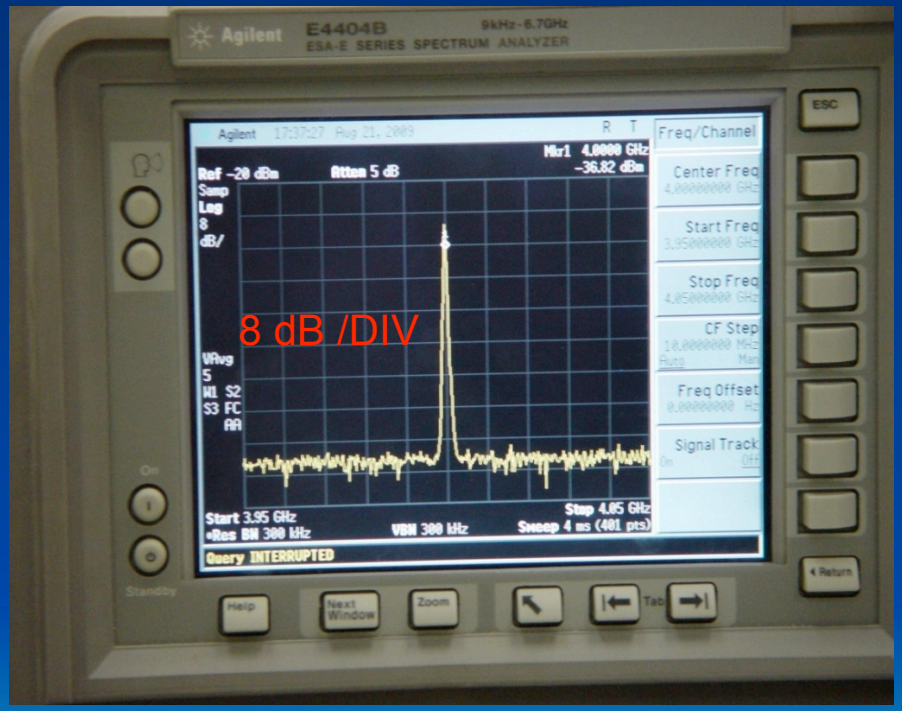
FRERQUENCY LOCKING AT CO_2 ABSORPTION LINE WING ---- PRINCIPLE & DIAGRAM



FRERQUENCY LOCKING AT CO2 ABSORPTION LINE WING

---- BEATING SIGNALS ON ESA



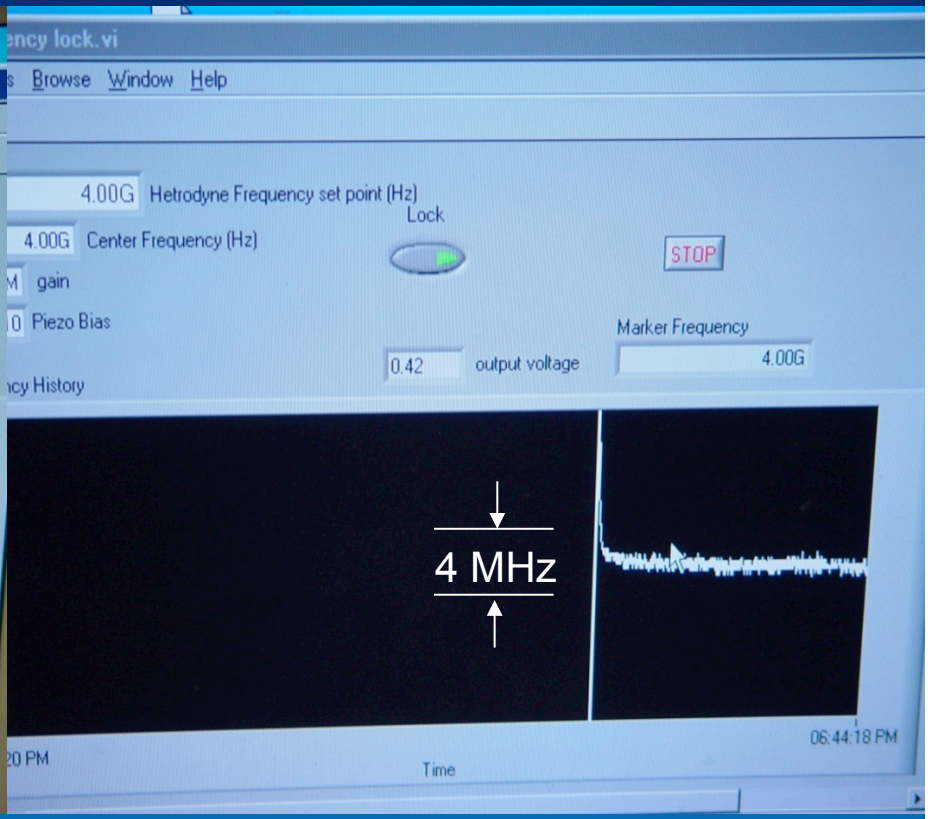


3 GHz BEAT SIGNAL

4 GHz BEAT SIGNAL

FRERQUENCY LOCKING AT CO_2 ABSORPTION LINE WING

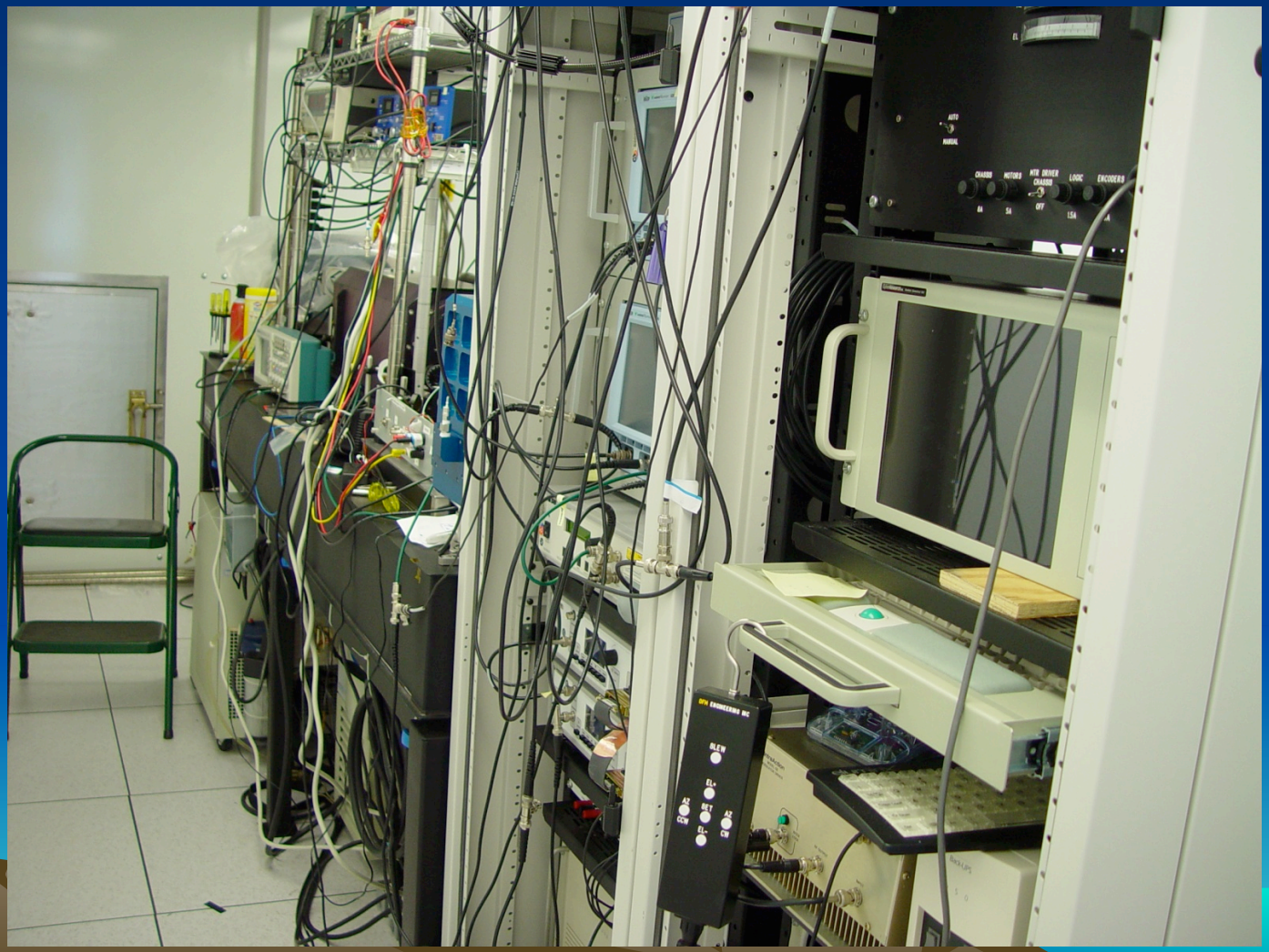
---- SHORT TERM STABILITY



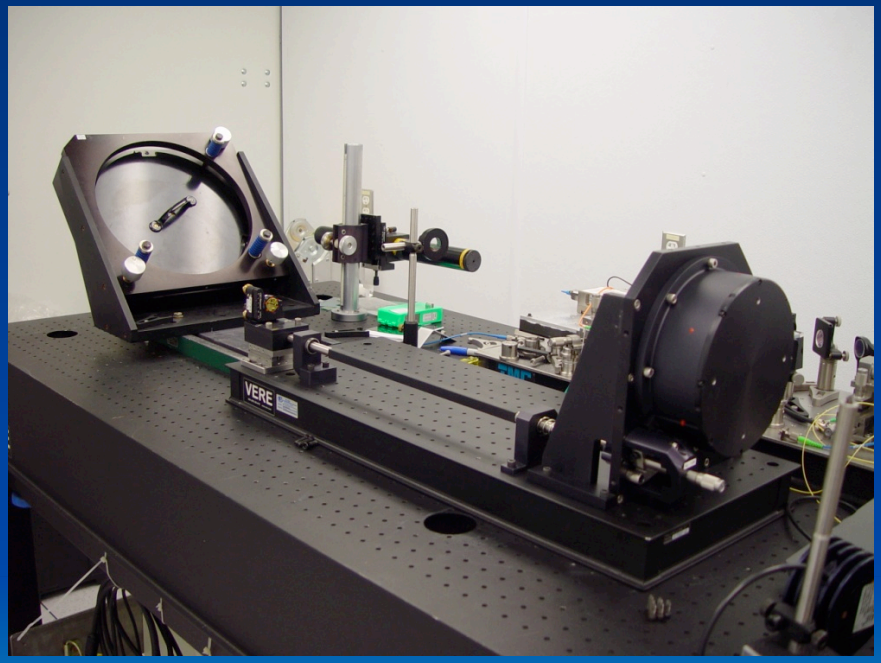
FREQUNCY LOCKING AT 3 GHz FROM THE CENTER

FREQUNCY LOCKING AT 4 GHz FROM THE CENTER

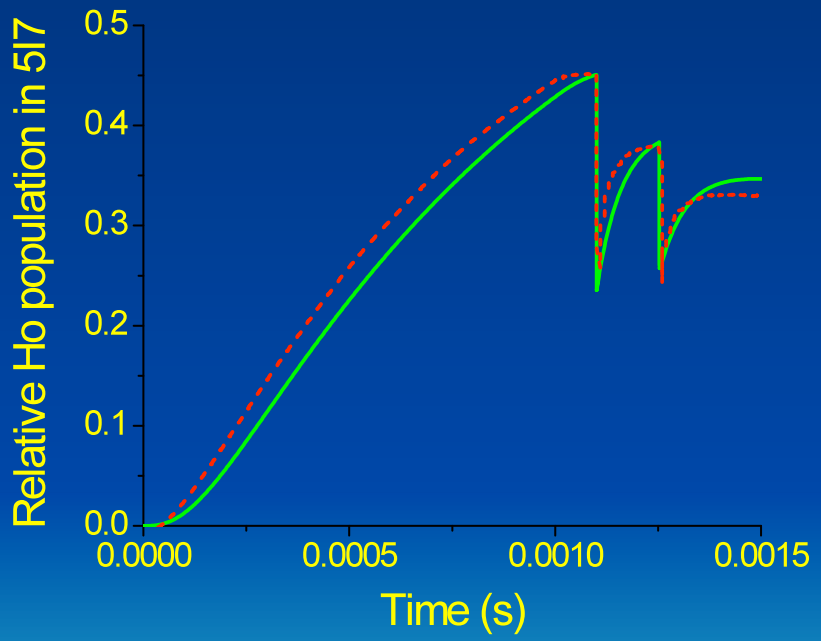
CO_2 Coherent DIAL in Trailer

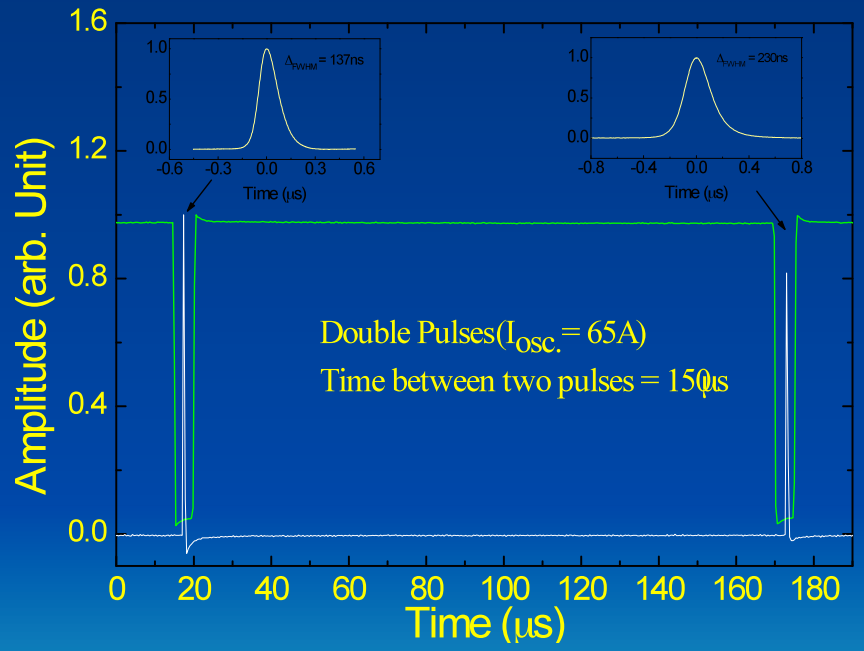


Telescope and Scanner

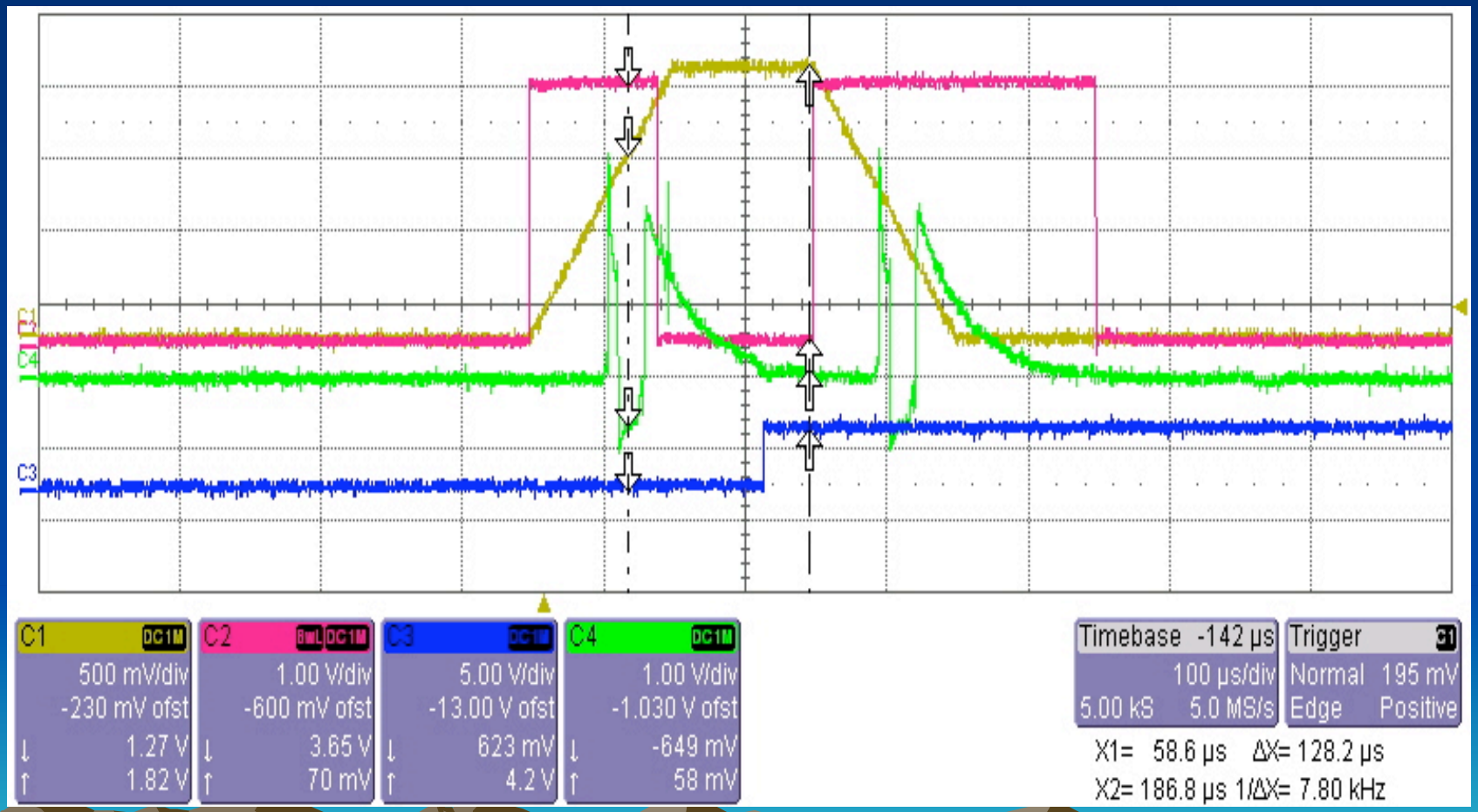


Double Pulsed 2-μm Laser Operation

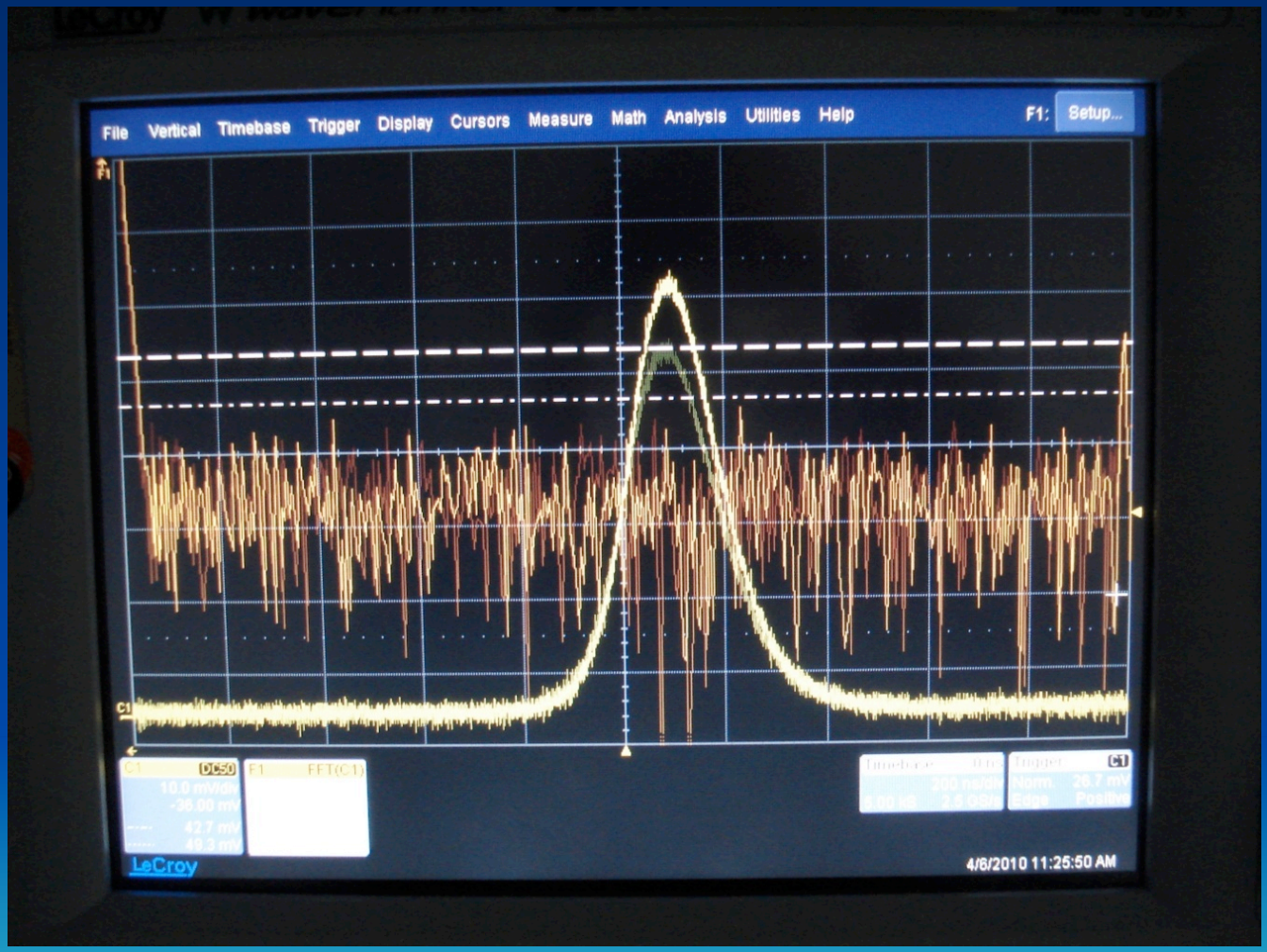




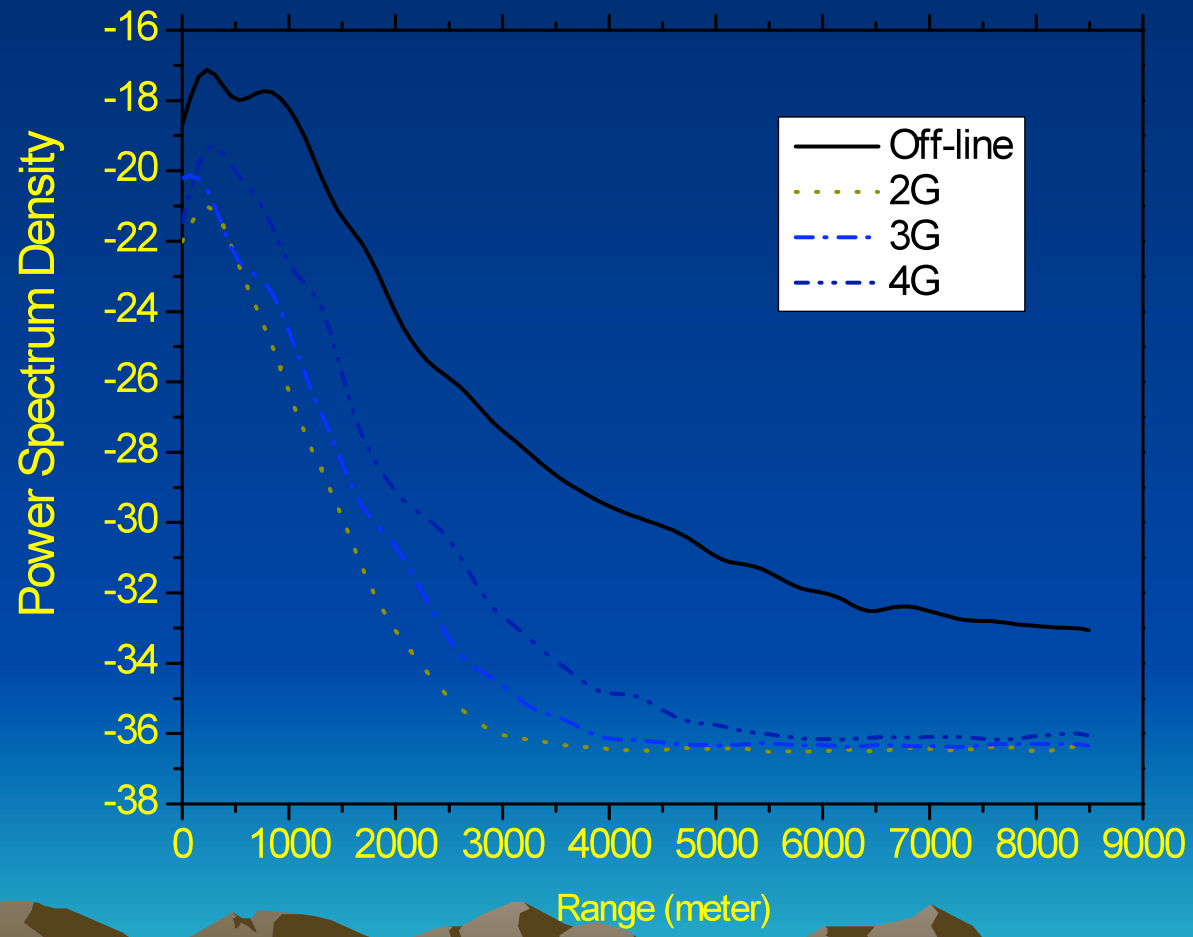
Double Pulse



Single Frequency



On-Off Return Signal



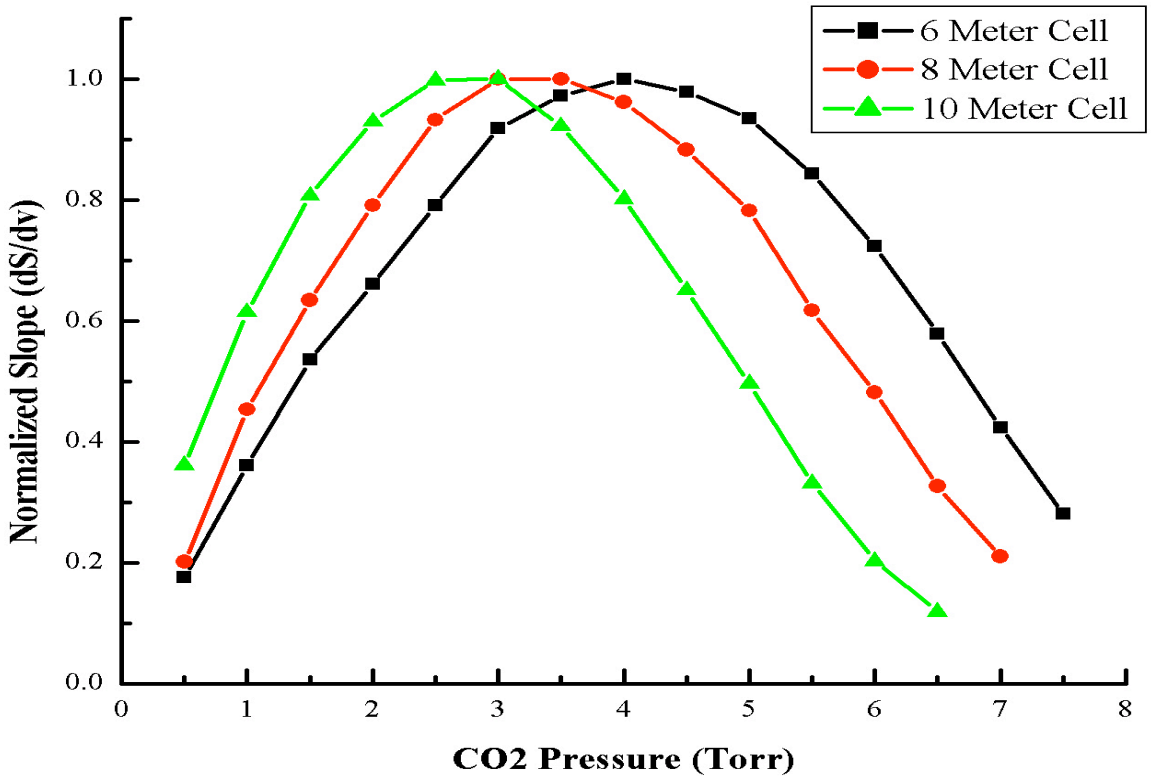
Summary

- 2-micron team has successfully developed a pulsed coherent DIAL, and demonstrated ground based measurement
- For the first time, a unique double pulse laser technique has been used in DIAL, which increase the laser efficiency and improves measurement accuracy
- Accurate laser wavelength control and switching has been demonstrated, which meets the frequency stability and accuracy requirement for the CO_2 DIAL.
- Team is developing a high repetition 2-micron transmitter for airborne CO_2 DIAL measurement

BACKUP SLIDES

FRERQUENCY LOCKING AT CO_2 ABSORPTION LINE CENTER

---- OPTIMIZATION OF FREQUENCY LOCKING



Atmospheric Return Signal